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Improvement Productivity and Quality by Using Lean Six Sigma: A Case Study in Mechanical Manufacturing

Minh Ly Duc[1], *Que Nguyen Kieu Viet*[1]

[1] *Van Lang University, 69/68 Dang Thuy Tram, Ward 13, Binh Thanh District, HCMC, Vietnam*

Email: minh.ld@vlu.edu.vn

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Abstract

Intelligent integrated production systems are always of interest to production planners. However, in order to deploy and improve from a mere processing factory to a processing factory with an integrated intelligent production system, it requires a team of employees, engineers, and managers to always have a spirit of innovation, continuously improving existing semi-automatic equipment into automatic ones, aiming to move towards a smart factory. The result of this research is to reduce waste in the process of assembling mechanical products by applying the DMAIC process (Define, Measure, Analysis, Improve, Control), lean six sigma tools, the test of variance, hypothesis testing and experimental design, IBM SPSS 2020, Matlab2019a and Minitab 18 software are used for data analysis and Solid work software is used to design and simulate mechanical parts. This study shows a systematic approach to analysis to find the root cause of defects in the product assembly process, a method of diagnosing defective products as well as the application of charts to the analysis of waste products, and improving quality by applying basic quality management tools such as Pareto charts, fishbone diagrams, value stream mapping, man-machine chart, and failure tree analysis (FTA). Clearly identify the types of waste such as components sliding on top of each other without rust, and surface roughness of metal products that do not meet the standards. Experimental design models and statistical models, and statistical tests are applied to Lean six sigma's DMAIC model in the process of analyzing the machining process. The results of analysis and process improvement have improved in a reduction of scrap in the assembly line of mechanical products by 59.66% per year, an increase in assembly-line productivity by 7.8% per year, and a decrease in waste costs incurred by 59.66% per year. The application of the DMAIC cycle to improve the quality of the assembly line of mechanical products, in addition to reducing waste, also reduces the quality cost of the assembly line.

1. Introduction

The significant growth of technology and the current market mean that rivalry among firms is expanding; therefore, enhancing quality and production operations is required for enterprises to compete (Pereira et al.). Many tools are used by businesses to manage quality, such as ISO certification, Total quality management (Pugna, Negrea, and Miclea Nandakumar, Saleeshya, and Harikumar Hakimi, Zahraee,

and Rohani). Lean Six Sigma is a technique used by many firms to enhance production and product quality, particularly in the last 20 years; Lean Six Sigma is seen as a powerful tool to help businesses improve efficiency, remove stages that add little value, and focus on speed (John and Kadadevaramath) (Uzorh, Olanrewaju, and I Nnanna). However, the quality improvement process necessitates continual improvement and a team of experienced specialists using the Define - Measure - Analyze - Improve - Control (DMAIC) cycle (Castro, De Camargo, and Junior). Businesses may regulate the machining process, detect variables impacting output, remove irregularities or changes in the machining process to increase efficiency, and satisfy client requests as quickly as possible (Hardy, Kundu, and Latif) (Lizarelli and De Toledo).

In Lean six sigma studies, DMAIC aims to provide an overview of the supply chain, assist managers in providing quality improvement solutions, develop a comprehensive defect improvement methodology for quality of manufacturing processes, and provide supporting documentation in various fields (Sodhi, D. Singh, and B. J. Singh) (Kregel et al.) (J. P. Costa, Lopes, and Brito). Typically, the study by Kregel and colleagues combined process mining with six sigma tools to process large volumes of data in manufacturing enterprises, showing that the successful application of six sigma will increase outstanding productivity growth in operational productivity (De Mast and Lokkerbol) (Srinivasan et al.). The study of Ismyrlis and Moschidis on integrating six sigma with the quality management system (QMS) between practice and theory (Gaikwad et al.). One of the solutions to improve business competitiveness and sustainable growth is to improve the performance of the Product Development Process (PDP) or use the Continuous Improvement (CI) philosophy. Businesses must pay attention and regularly implement improvement activities according to the process and control and closely monitor (Minh, Ni, and Hien). Therefore, the DMAIC cycle will help businesses identify areas for improvement and challenges faced in the improvement process and then offer appropriate improvement plans (Smetkowska and Mrugalska) (Soliman). With businesses increasingly interested in improving process speed, customer satisfaction, costs, or product quality, it is indispensable to apply lean in production operations. Lean manufacturing is a technique that helps businesses effectively eliminate waste and defects in the production process (Nandakumar, Saleeshya, and Harikumar) (Ranade et al.) (Sharma et al.).

Implementing Lean Six Sigma, the DMAIC cycle into continuous improvement or quality management activities brings many benefits in machining process optimization, eliminating defects that have no value in the process production (Tsarouhas) (Hakimi, Zahraee, and Rohani). Each stage will use production process management tools Value Stream Mapping, Pareto analysis, and Total Equipment Efficiency to enhance productivity and overall quality characteristics of manufactured products (Priya, Jayakumar, and Kumar) (Tampubolon and Purba) or applying many qualities management tools such as SIPOC analysis, cause-and-effect diagrams (T. Costa, Silva, and Ferreira). With the DMAIC and six sigma cycles, the entire process built on process capability metrics and developed using statistical quality control methodologies, DMAIC will deliver ground-breaking quality improvements quickly (Ismyrlis and Moschidis) (Klochkov, Gazizulina, and Muralidharan). However, managers need to consider when applying the DMAIC cycle because there are still some limitations on the accuracy of the methodology and weak data aggregation techniques [27] [28].There have not been any applied studies combining statistical testing, empirical research, and computer vision into the DMAIC cycle of the Lean six sigma method to research and improve the outsourcing process in actual enterprises. Controlling labor safety in the environment using automatic processing machines is necessary and urgent. Computer vision technology contributes to solving this problem.

A successful industrial organization not only has a good production plan but also a plan to control and improve the quality of product outsourcing at the stage in an integral part of the competitive world now and in the future. Especially, the assembly process of products depends on the workmanship. Improving product quality, eliminating dependence on workers' skills and improving productivity, and reducing labor costs and input materials are the criteria that outsourcing companies are always thinking about. solution for an optimization. The focus

of this research is on the development of part selection and dimensioning testing tools as well as the operation of assembly components that replace the working skills of workers, and develop test data collectors and results in analysis using an online test system. In the present time, with the strong rise of economies in Asian countries, in which China is the leader in making the price competition of products, accompanying customers' requirements on the quality of output. the higher the product. Therefore, the top managers in each company have to think and find a direction for the company, in addition to maintaining profits for the company in a time of fierce competition, they also have to find ways to improve product quality to meet the increasing requirements of customers. Different companies find their own different directions to meet their own customer needs. The same goes for Neosy Company in the outsourcing and assembly stage of Linear bush, quality control, tool improvement, output improvement and profit increase are what the company's management always focuses on to improve continuous progress. Linear Bush is shown in Figure.1, a ball-based linear guide used in conjunction with a cylindrical shaft. This product provides linear movements with minimal friction to deliver precise simple motion. A system of grooves containing iron or steel balls is fitted instead of a material with a low coefficient of friction. Working principle: the sliding motion, in this case, is converted into the rolling motion of the balls inside the sliding bearing.

This study offers the following benefits: (1) Incorporating statistical techniques, experimental design (Pravin et al.) into Lean six sigma method, analyzing and improving the operation of the production process (Ranjith et al.) at a mechanical product processing company. (2) Control and improve labor safety at processing lines using automatic machines by computer vision technology. (3) Improve productivity and improve product quality by applying continuous improvement. (4) Create a stimulating link between the learning environment and the actual production environment at the company. Remove barriers in people's thinking about the research environment and the practical working environment.

In this paper, we propose to change the machining tools to improve the surface roughness and create a smooth slip measurement system between the ball and the slider bar to identify the OK NG measurement results by the measuring system. The paper is made as follows: Part II describes case study for improvement, methodology and raw materials in part III, part IV state the results and discussion, Part V shows the conclusions and directions for future work.

2. Case Study for Improvement

This study aims to eliminate waste products, improve productivity and eliminate non-value-added activities in the production line. Human factors and machine tool tools are carefully observed and analyzed using DMAIC techniques, analyzing the current state of the machining line, setting improvement goals, and implementing improvement measures. Industrial Engineering Tools, Value stream mapping, hypothesis testing, CIM (Computer Integrated Manufacturing), and Problems solving Analysis are applied to analyze the root causes of non-value-added activities, generate costs in production, and implement improvement activities to Eliminate waste and bring profit to the machining line. Output capacity of Neosy processing factory is 1984 sets per year and waste generation is 131 sets per year, waste generation rate is 6.6 % per year (cost is 12570 USD per year). The generation of this waste not only reduces the processing productivity but also makes the company's profit seriously affected, this study analyzed the current status of the processing line and received the results found that the outsourcer was doing well, but there were still some activities that gave rise to errors that needed improvement. This study is meant to analyze in detail the factors that cause waste, and the impact of the production environment that causes waste. The main job of improvement activities (Kaizen) is to perform improvement activities to eliminate waste, reduce inefficiencies, eliminate downtime, reduce waste, and eliminate repair work. Post-processed products and improve overall machining efficiency (OEE). Continuous improvement activities in the 6-step quality control model follow the PDCA cycle along with positive thinking about the manufacturing process re-signing through Poka-yoke theory, see Table 1. Specifically, designing tools, applying statistical techniques (Ranjith et al.) , designing experiments (R et al.) and replacing human manipulation processes and automating

operations in production activities.

3. Materials and Methods

3.1. Define

Step 1 (Introduction current situation): Outlining the production process of an operating process at a mechanical goods line company, approaching the process according to the Toyota solution method (scene, thing, state), approach to the Toyota production system. See Table 2 for the manufacturing process approach.

Step 2 (Set the goal, creating activity action and root cause analysis): The model "S.M.A.R.T" (Specific, Measurable, Achievable, Relevant, Time-Bound) is used to set goals to realize process improvement. The more specific the goal, the easier it is to understand and within the reach of achievable. The control chart (Formula from (1 – 5)) is used to monitor the stability of the process and the histogram (Formula from (6 - 11)) is used to check the process performance.

$$\bar{X}_i = \frac{\sum_{i=1}^{n} X_{ij}}{n} \tag{1}$$

$$\bar{R} = \frac{R_1 + R_2 + \cdots + R_n}{m} \tag{2}$$

$$CL = \tag{3}$$

$$LCL = -A2\bar{R} \tag{4}$$

$$UCL = +A2\bar{R} \tag{5}$$

$$\bar{x} = \frac{\sum_{i=1}^{n} x}{n} \tag{6}$$

$$S = \sum x^2 - \frac{\left(\sum x_i\right)^2}{n} \tag{7}$$

$$C_p = \frac{(USL - LSL)}{6 \times \sigma} \tag{8}$$

$$C_{pk1} = \frac{\left(USL - \bar{X}\right)}{3 \times \sigma} \tag{9}$$

$$C_{pk2} = \frac{\left(\bar{X} - LSL\right)}{3 \times \sigma} \tag{10}$$

$$C_{pk} = min(C_{pk1}; C_{pk2}) \tag{11}$$

3.2. Measure

Step 3: (Factor analysis, check and evaluate of measurement counter): In the 3 production lines, it is necessary to determine which lines give rise to waste products. The Bootstrap ANOVA method was used to test the mean of k populations. Formulas from (12) to (18) are applied.

$$\bar{Y}_i = \frac{1}{n_i} \sum_{j}^{n_i} Y_{ij}, \quad i = 1, \ldots, t \tag{12}$$

$$SSD_i = \sum_{j=1}^{n_i} \left(Y_{ij} - \bar{Y}_i\right)^2, \quad i = 1, \ldots, t \tag{13}$$

$$\sum_{i=1}^{t} \sum_{j=1}^{n_i} (Y_{ij} -)^2 = \sum_{I=1}^{t} SSD_i + \sum_{i=1}^{t} n_i \left(\bar{Y}_i -\right)^2 \tag{14}$$

$$Y_{ij} - = \sum_{i'} \sum_{j'} C_{i'j'} Y_{i'j'} \tag{15}$$

$$E\left(MSW\right] = \sum_{I=1}^{t} v_i E\left(\frac{SSD_i}{n_i - 1}\right] = \sigma^2 \sum_{i=1}^{t} v_i = \sigma^2 \tag{16}$$

$$E\left(MSB\right] = \sigma^2 \frac{1}{t-1} \sum_{i=1}^{t} n_i \tau_i^2 \tag{17}$$

$$F = \frac{MSB}{MSW} \tag{18}$$

TABLE 1. **Proposed 6-step model methodology**

P (Define)	P (Measure)	D (Action)	C (Improve)	A (Control)
Step 1: Introduction current situation	Step 3: Factor analysis, check and evaluate of measurement counter	Step 4: Implement measurement counter	Step 5: Confirmation of effect, standardization work	Step 6: Reflection / remaining problems and plan for the future
Step 2: Set the goal, creating activity action and root cause analysis				

TABLE 2. **Steps to approach the production process**

Step	Approach implementation method	Content implementation approach
Step 1:	Workflow Diagram	Stand at a fixed position for about 30 minutes and observe carefully and in detail the operation at the stage to be analyzed.
Step 2:	Process flow chart and Human - Machine activity chart	Re-draw the processing process with a flow chart, outline a human-machine interaction flowchart using a Man-Machine chart and clearly define the time of each operation, distinguishing wasteful and profitable operations. that have value-added and create value stream mapping of manufacturing process
Step 3:	Hand operation chart or hand operation chart	Record a video and observe the correlation between the operator's operation and the operation of the official machine, determine whether the operator's left- and right-handed operation compared to the operation of the machine mechanism is convenient or not. , determine the operation that generates waste

To evaluate the accuracy of the type of processing machine that generates waste products, the expectation test when knowing the variance with a large sample size is applied. Implement a processing machine with a large enough number of samples and apply the formula from (19 - 21) to check the accuracy of the cause of the generation of waste.

$$\frac{\left(\bar{X}-\mu\right)}{\left(\frac{\sigma}{\sqrt{n}}\right)} \sim Z \tag{19}$$

$$\frac{\left(\bar{X}-\mu_0\right)}{\left(\frac{\sigma}{\sqrt{n}}\right)} \sim Z \tag{20}$$

$$R = \left(\bar{X} > \mu_0 + \frac{Z_\alpha \sigma}{\sqrt{n}}\right] \tag{21}$$

Re-check the accuracy as a waste product generated by the machine, process the same product on a different machine and use the test of expected deviation, known variance with dimensions. Large sample size for analysis, formulas from (22) to (24) are applied.

$$\frac{\left(\bar{X}_1-\bar{X}_2\right)-(\mu_1-\mu_2)}{\sqrt{\frac{S_1^2}{n_1}+\frac{S_2^2}{n_2}}} \sim Z \tag{22}$$

$$\frac{\left(\bar{X}_1-\bar{X}_2\right)}{\sqrt{\frac{S_1^2}{n_1}+\frac{S_2^2}{n_2}}} \sim Z \tag{23}$$

$$R = \left(\left(\bar{X}_1-\bar{X}_2\right) > Z_{\frac{\alpha}{2}}\sqrt{\frac{S_1^2}{n_1}+\frac{S_2^2}{n_2}}\right] \tag{24}$$

3.3. Analysis

Step 4: Implement measurement counter: Analyze the object and determine the factors affecting the output results of the object by experimental method and at the same time evaluate the impact of the physic - mechanical properties of the affected object to the output of that object by the experimental method. Evaluate the results of object application after experimental design and application to the machining process by statistical and measurement methods. Also rebuild the future value stream map of the whole machining process. To evaluate the elemental composition (concentration) of CBN of the grinding wheel, the completely randomized design (CRD) method is applied according to the formula from (25 - 28) and Analysis of variance ANOVA factors in the experiment, the formula from (29) to (31) is applied.

$$Y_{ij} = \mu + \tau_i^A + e_{ij}, \quad i = 1, 2, \ldots, a; \quad j = 1, 2, \ldots, n \qquad (25)$$

$$\sum_{i=1}^{a} \tau_i^A = 0 \qquad (26)$$

$$E\left(e_{ij}\right] = 0 \quad v\grave{a}V\left(e_{ij}\right) = \sigma^2 \qquad (27)$$

$$= \frac{1}{a}\sum_{i=1}^{a} \bar{Y}_i \qquad (28)$$

$$SST = \sum_{i=1}^{n}\sum_{j=1}^{m} \left(y_{ij} -\right)^2 = SS_{Treatm} + SS_E \qquad (29)$$

$$ss_{Treatm} = n\sum_{i=1}^{n}\left(\bar{y}_i -\right)^2 \qquad (30)$$

$$SS_E = SST - SS_{Treatm} \qquad (31)$$

Evaluation of the impact factor between the grinding wheel and the rotational speed of the eyebrow stone after improvement has an impact on the quality of the rough surface of the mechanically processed products, the binary experimental method, and the analysis of variance is applied to the analysis, the formulas from (32) to (38) are applied.

$$A = \frac{(ab + a - b - (1)]}{2n} \qquad (32)$$

$$B = \frac{(ab - a + b - (1)]}{2n} \qquad (33)$$

$$AB = \frac{(ab - a - b + (1)]}{2n} \qquad (34)$$

$$SS_A = \frac{CT_A^2}{2^2 n} = \frac{(ab + a - b - (1)]^2}{4n} \qquad (35)$$

$$SS_B = \frac{CT_B^2}{2^2 n} = \frac{(ab + b - a - (1)]^2}{4n} \qquad (36)$$

$$SS_{AB} = \frac{CT_{AB}^2}{2^2 n} = \frac{(ab + (1) - a - b]^2}{4n} \qquad (37)$$

$$SS = \sum_{i=1}^{2}\sum_{j=1}^{2}\sum_{k=1}^{n} Y_{ijk}^2 - \frac{Y^2}{4n} \qquad (38)$$

Re-evaluating the system after improving whether there is a waste product or not, the method of testing the rate using the statistical function is the sample ratio P with a large enough sample size, the normalized sample ratio with a normal distribution is applied. Used for analysis, formulas from (39) to (43) are developed.

$$\frac{P - p}{\sqrt{pq/n}} \sim Z \qquad (39)$$

$$\frac{P - p_0}{\sqrt{p_0 q_0/n}} \sim Z \qquad (40)$$

$$R = \left(P < p_0 - Z_{\frac{\alpha}{2}}\sqrt{\frac{p_0 q_0}{n}},\ P > p_0 + Z_{\frac{\alpha}{2}}\sqrt{\frac{p_0 q_0}{n}}\right] \qquad (41)$$

$$R = \left(P < p_0 - Z_{\alpha}\sqrt{\frac{p_0 q_0}{n}}\right] \qquad (42)$$

$$R = \left(P > p_0 + Z_\alpha \sqrt{\frac{p_0 q_0}{n}} \right] \quad (43)$$

Checking the quality of the following products for stability and high accuracy are the two criteria to evaluate the performance of the system after the improvement, taking the same product to run on the same processing machine. The improved system and the method of testing the variance are applied from formulas (44) to (47). At the same time, the same product is run on 2 different machines, and the method of testing the expected deviation when the variance is unknown with a large sample size is applied analysis according to the formula from (48) to (50).

$$\frac{(n-1)\,S^2}{\sigma^2} \quad (44)$$

$$\frac{(n-1)\,S^2}{\sigma^2 - x^2_{n-1}} \quad (45)$$

$$\frac{(n-1)\,S^2}{\sigma_0^2 - x^2_{n-1}} \quad (46)$$

$$P\left(S^2 > \frac{x^2_{\alpha,\, n-1}\sigma_0^2}{n-1} \right\} = \alpha \quad (47)$$

$$\frac{\left(\bar{X}_1 - \bar{X}_2\right) - (\mu_1 - \mu_2)}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \sim Z \quad (48)$$

$$\frac{\left(\bar{X}_1 - \bar{X}_2\right)}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \sim Z \quad (49)$$

$$R = \left(\left(\bar{X}_1 - \bar{X}_2\right) < -Z_\alpha \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}} \right] \quad (50)$$

3.4. Improve

Step 5: Confirmation of effect, standardization work: Modeling Integrated Manufacturing System (CIM: Computer Integrated Manufacturing), Modeling positions, stages or activities in the production process can apply production methods using computer control production. This integration allows individual processes to exchange information with each department. Production can be faster and less error prone thanks to the integration of computers (Saravanakumar et al.) . It is very necessary to build an intelligent control system in the production process. From Figure 1, the intelligent control system is the system that applies computer tools that can self-adjust or diagnose abnormality, in terms of parameters of the machining system, it is necessary to repeat a system calling the program automatically, called the DNC: Digital Numeric Control program. In terms of manufacturing process parameters, it is necessary to iterate an automatic measuring system, check and feed the results into the system automatically, which is called a measuring system or Poka-yoke operation.

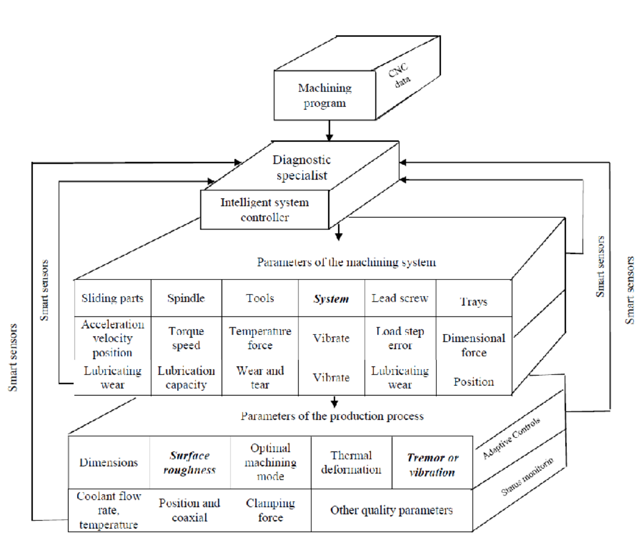

FIGURE 1. Typicalmonitoring tasks of an intelligent machining system

To use the intelligent production control system, it is necessary to have a safety warning system in the control. Specifically, it is necessary to set up a computer vision system to identify people, control the operation of trained people using the system, if not the right person is trained, the system will automatically warn and mirror, do not allow operation.

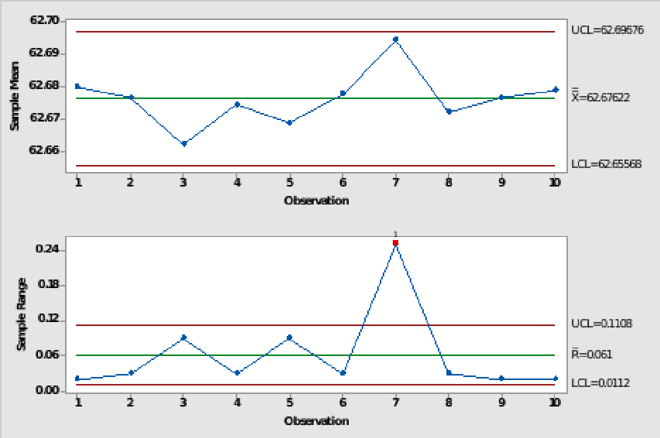

FIGURE 2. .Control chart of roughness of hole

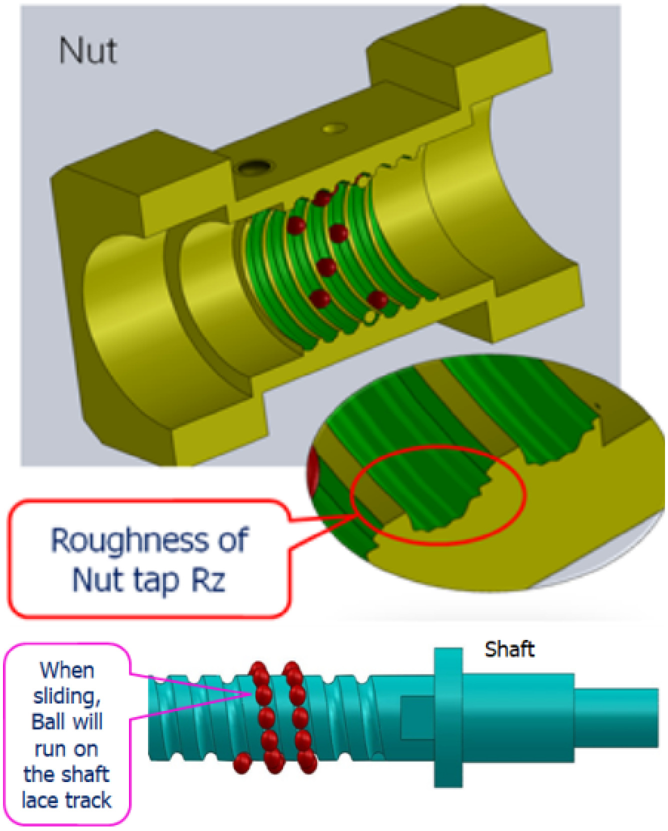

FIGURE 3. Roughness of hole

Step 6: Reflection / remaining problems and plan for the future: An activity to improve tools and processing machines in the production process with the goal of eliminating waste and increasing productivity, increasing profits in business and the post-improvement result operator is the operator at the machining line, it is very necessary to investigate the operator's satisfaction with the results of this improvement activity, it is necessary to evaluate the influencing factors such as in terms of technical factors, usefulness factors and usefulness factors, the PLS-SEM model is applied to analyze the operator's satisfaction and thereby draw experience for the times of improvement.

4. Result and Discussion

Step 1 and step 2: Collect the surface roughness measurement results of 120 products, the results show the instability of the measured dimensions, see Figure (2&3) Control chart of Roughness of hole, need to improve the stone grinding and polishing the surface of the hole of the product at the finishing stage.

The surface roughness is not up to the standard and is unstable, causing time (35 minutes) to both check and calibrate so that the product runs smoothly, at the assembly stage, and it takes time to re-check. roughness of the product after processing, this is a wasteful step. The value stream mapping chart of the current state of the processing line shows that the total lead time of a product is 1190 minutes, the total cycle time is 995 minutes and the value add time is 443 minutes.

Total lead time (1190 minutes) at the machining stage, need to improve the machining process to improve the dimensional stability of the hole surface roughness of the product, the FTA (Failure Tree Analysis) model is applied for analysis. The cause of the error of instability of the hole surface roughness, resulting in additional roughness measurement and time-consuming calibration, checking the smooth operation of the product after assembly, see Figure 4, FTA analysis model for dimensional instability error of hole surface roughness. The results of the FTA analysis show that the setting type of the hole grinding wheel is the key factor causing the instability of the hole roughness. In addition, it is necessary to design a system to check the smooth operation of the product after assembly and link the data on the measuring system. Analysis of the cause of the error arising by fishbone diagram found that smoothly Judge NG and Parts Preparing NG were the two main causes, see Figure 5.

When sliding, Ball will run on the shaft lace track and is not smooth making the details not work, see Figure 6. because the Nut surface (Figure 3.b) is not rough enough to cause the Ball to get stuck, then It takes a lot of time to fix.

Step 3:Take 10 similar products to run on 3 machines A1, A2 and A3 in the processing line and

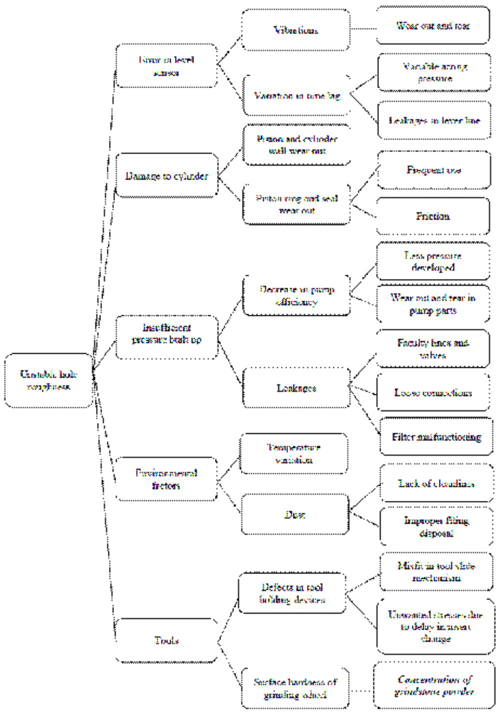

FIGURE 4. FTA analysis model for dimensional instability error of hole surface roughness

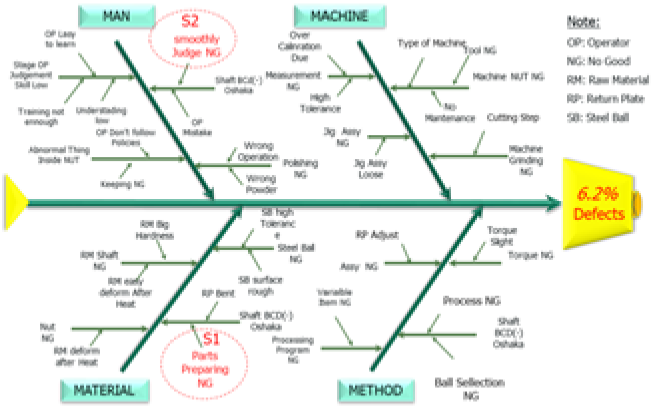

FIGURE 5. Fishbone diagram analysis

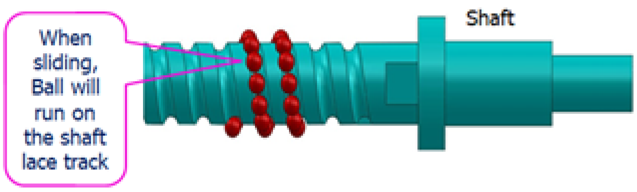

FIGURE 6. Ball run on the shaft

use the formula from (12) to (18) and Minitab 18.0 software to run the analysis and output the results,

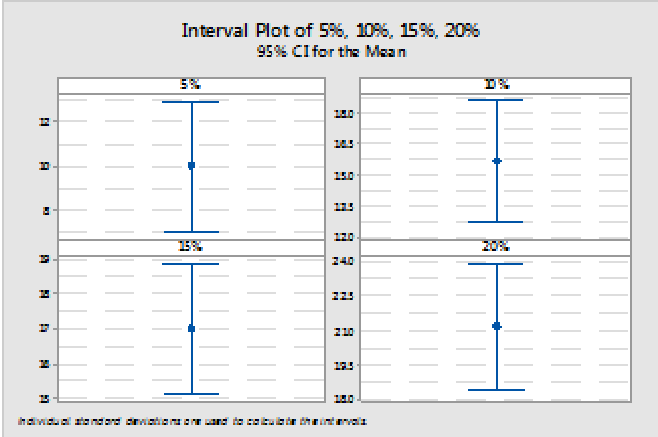

FIGURE 7. Interval plot analysis

look at the Table 3 results of ANOVA analysis, statistical value F=14.02 and P-Value = 0.000. Therefore, the conclusion rejects hypothesis H_0. That is, the roughness quality from the 3 machines is different. The 95% confidence intervals for the mean parameters and the results for machine A2 and A3 are the same, machine A1 is completely different.

Recheck the machining stability of the hole surface roughness size at machine A1, take 50 products for machining and use the hole surface roughness meter from product 1 to product 50, sample average value calculated as 34.45. Formulas from (19) to (21) are applied, with α = 0.05 and R=[$\bar{X}>$ 33.958], H_0 is rejected. Concluding that the dimensional quality of the product surface roughness is not stable.

Continue to perform machining with the method of taking 50 machining samples on machine A1 and 60 machining samples on machine A2, measuring the size of the surface roughness of the hole with a specialized gauge. Sample mean and sample variance are shown in Table 4. Applying the formula from (22) to (24) gives sample mean deviation, $D = \bar{X}_1 - \bar{X}_2 = 26.38 - 25.42 = 0.96$, with α = 0.05 and $R = (D < 0.57]$, sample mean deviation into the rejection region R, so H_0 is rejected. In conclusion, the performance expectation of machine A1 is not as good as the performance expectation of machine A2.

Step 4: Carry out a survey of 4 levels of CBN abrasive powder concentration of 5%, 10%, 15% and 20%. 6 test pieces are made at each test piece level and all 24 test pieces are tested for roughness at the same gauge, the test data shows the load Table

TABLE 3. Results of ANOVA analysis

Machine No.	Sample	Mean	STDEV	SS	MS	F	P-Value
A1	10	71.06	11.42	11366	5683	14.02	0.000
A2	10	104.61	27.87	10941	405		
A3	10	117.18	17.56	22306			

TABLE 4. Analysis of sample mean and sample variance

	Machine A1	Machine A2
Sample size	50	60
Sample mean	26.38	25.42
Sample variance	3.45	3.06

5 and figure 10, Interval plot analysis. Analysis of variance ANOVA of factors in the experiment, the formula from (25) to (31) is applied and the results are established in Table 6. The results show that F_0 = 19.9 and with the significance level of 1%. Conclude that the amount of CBN abrasive powder in the grinding wheel significantly affects the quality of the hole machined surface of the product.

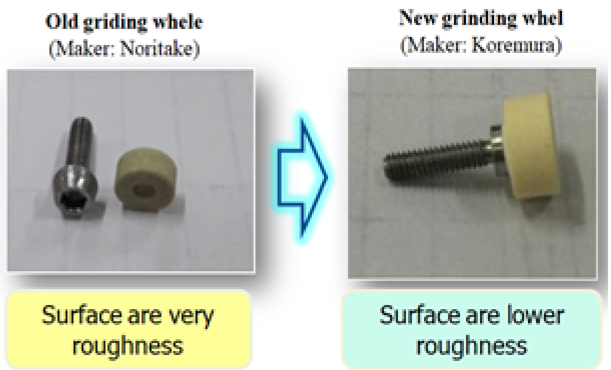

FIGURE 8. Picture of grinding stone before and after

Conduct experiments to verify the impact of grinding wheel concentration (A) and grinding speed (B) on the quality of the hole surface roughness of the product, with the experimental design being 3 times with the results as shown in Table 7. Applying formulas from (32) to (38). Calculate the results of empirical analysis and show in Table 8, analysis of variance ANOVA. Analytical results show that with α = 0.05 and P-values of A and B respectively 0.0001, 0.0024, this proves that factors A and B have an impact on the stability of the hole surface roughness of the product. The P-value of AB is 0.1826, showing that the interaction of the two factors has no effect on the surface roughness.

From the experimental analysis results, we have selected a suitable grinding wheel for the production process, Figure 8 is the improved pre-improved (supplied by Noritake) and post-improved (supplied by Koremura).

Take 200 samples run on a new grinding wheel, then use a roughness meter to check the stability of the hole roughness size. Formulas from (39) to (43) are applied to the analysis of the results, with α = 0.05 and looking up the table, Z_α = 1.645, the calculation results have R = [P< 0.1535] and R = [P> 0.2465]. In conclusion, H_0 is rejected and the rate of quality stability surface roughness is very good. Continuing to take 30 product samples for running on the same machine, formulas from (44) to (47) were applied for analysis, with α = 0.05 and R=[S2 > 2.201] and H_0 accepted. Show that the hole surface roughness quality is stable. Using the same modified grinding wheel for 2 different processing machines, conduct the experiment as follows, run machine 1 with 10 samples and run machine 2 with 12 samples, formulas from (48) to (50) is applied, with α = 0.05 and R=[D<-1.606; D>1.606] and H_0 are accepted, demonstrating that the surface roughness quality of the hole run on two different machines and using the same grinding wheels gives stable results.

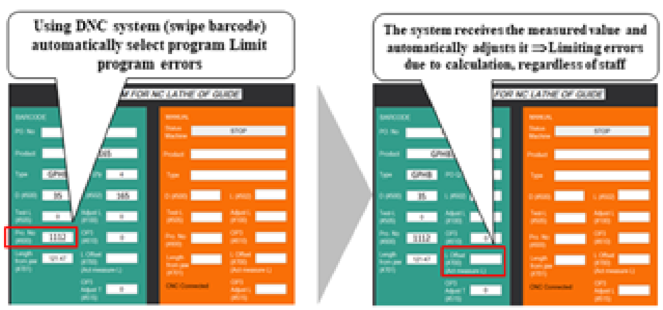

FIGURE 9. DNC program screen interface

Step 5: Build an intelligent system in processing factories using automatic lathes, deploy the method of calling the CNC machining program using the DNC model according to Diagram 1 the DNC program call flow diagram for machine automatically

TABLE 5. Test result analysis

Observation								
CBN abrasive powder concentration (%)	1	2	3	4	5	6	Total	Mean $\bar{Y}$
5	7	8	15	11	9	10	60	10.00
10	12	17	13	18	19	15	94	15.67
15	14	18	19	17	16	18	102	17.00
20	19	25	22	23	18	20	127	21.17
							$\sum_{ij} y_{ij} = 383$	15.98

TABLE 6. ANOVA analysis table of CBN abrasive power composition in grinding wheel

Variation	D.F	S.S	M.S	Statistics F_0
How to process CBN grinding wheel powder	3	382.79	127.60	19.6
Random error	20	130.17	6.51	
Total	23	512.96		

TABLE 7. Experimental results

Experiment	Y			S
A^-B^-	28	25	27	80
A^+B^-	36	32	32	100
A^-B^+	18	19	23	60
A^+B^+	31	30	29	90

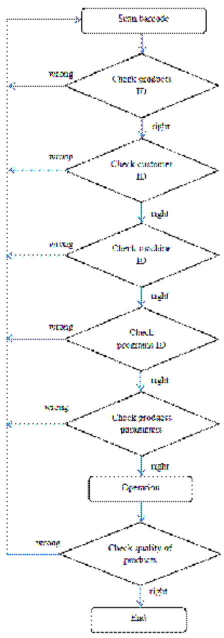

Diagram 1: DNC program flowchart

and as a result, eliminates human dependence on selecting the machining program and entering the machining parameters required by the design table. The DNC program links from the customer's ID number, the ID of the order to be processed and the type of machine, the machining program and the selection of the most suitable machining tolerance. The DNC program interface screen is shown in Figure 9

A system of data collection to check the smooth functioning of the product is implemented, and as a result, the inspection time is significantly shortened, as well as the quality assessment that is mistaken for an OK product that is judged as a waste products. Figures 10 show the automatic test system.

To evaluate the linearity of the product smoothness measuring instrument system, we used 5 samples (with different measuring ranges running at 0.1, 0.5, 0.7, 0.9 and 1.2) and each sample measured 5 times. Apply the linearity evaluation formula (51) and the result is a stable response system, the mea-

TABLE 8. Analysis of variance ANOVA

SOVSS	DOF	MS	F_0	P
A 208.33	1	208.33	53.15	0.0001
B 75.00	1	75.00	19.13	0.0024
AB 8.33	1	8.33	2.13	0.1826
E 31.34	8	3.92		
Total323.00	11			

surement linearity response graph is as shown in Figure 11.

I t I = I a I / [s/(∑(xi-x)2)1/2] ≤ tgm-2,1-a/2 (51)

FIGURE 10. The automatic testsystem

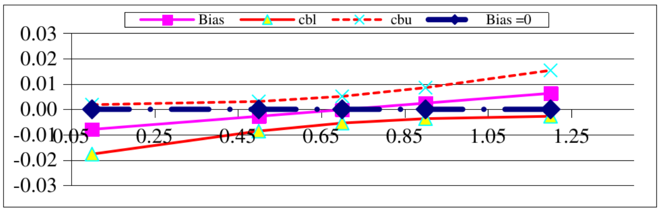

FIGURE 11. Linearity rating

Carry out an assessment of the measurement system error by taking 12 samples and giving 1 person to measure under the same measuring conditions, apply the formula from (52) to (55) calculate the measurement result and the result is the accuracy. Sample standard deviation = 0.23 is within the allowable range. Demonstrate that the measurement of the measuring system is stable.

$$Bias_{mean} = \frac{\sum_{i=1}^{n} Bias_i}{n} \quad (52)$$

$$\bar{X} = \frac{\sum_{i=1}^{n} (X_i)}{N} \quad (53)$$

$$\sigma_r = \sqrt{\frac{\sum_{i=1}^{n}\left(X_i - \bar{X}\right)^2}{n-1}} \quad (54)$$

$$Bias_{mean} - \left(\sigma_b \left(t_{v,1-\frac{\alpha}{2}}\right)\right] \leq 0 \leq Bias_{mean} + \left(\sigma_b \left(t_{v,1-\frac{\alpha}{2}}\right)\right] \quad (55)$$

In addition, in order for the intelligent production system to operate safely and for the best results, the operator of the automatic processing machine system must have sufficient skills and operating qualifications. This is the reason why it is necessary to develop a safety alert system at work with a computer vision system that identifies the right people to operate. Specifically, only qualified, trained and certified employees on the computer vision system can operate the specified machine correctly. If the person is not recognized by the computer vision system, the alarm will immediately sound and the system will be locked. Computer vision algorithm flowchart, see Figure 12.

Step 6: Survey of operators at Neosy on the results of using improvement activities. Machine maintenance technicians, machine operators and plant field managers were selected for the survey. Implement a random drawing method as this is easy for researchers to do. Everyone takes a survey at least once. The survey sampling criterion was that all were aware of tool improvement activities. The survey questionnaire refers to Neosy's past improvement activities. Each research variable is implemented through at least three measures. The survey questionnaire was conducted in Vietnamese. Use 5-point Likert scale to conduct data collection survey. To ensure that the questionnaire was appropriate, it sent three managers (production manager,

technical director, and quality assurance director) for comments. The author completed a questionnaire survey based on the opinions of three managers. Survey a total of 200 questions and eliminate 50 samples because the survey results do not meet the requirements due to not carefully reading the required content of the survey questionnaire. A total of 150 questionnaire samples give valid results and are used in the PLS-SEM analysis model. To use Smart PLS 3.0 software for data analysis. The results data collection shows that 66.67% are male and 33.33% female. Their qualifications are mainly 12, accounting for about 80% of the details in Table 9.

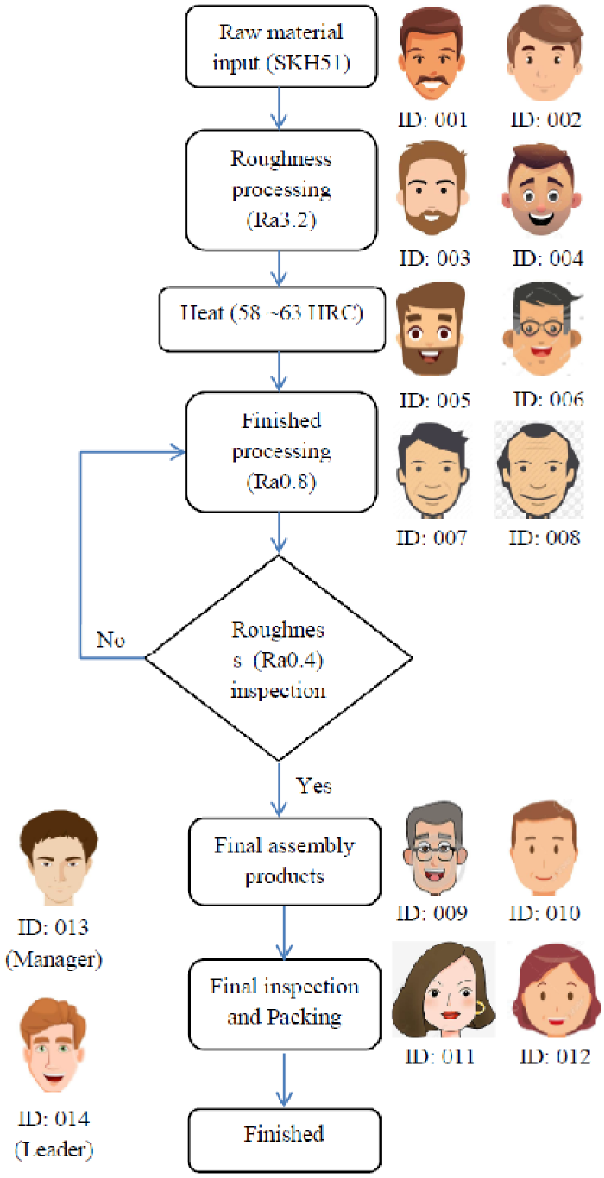

FIGURE 12. **Face recognition system**

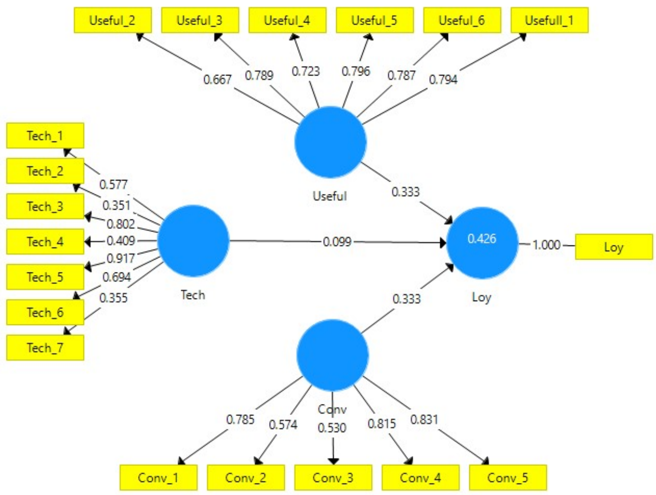

FIGURE 13. **PLS-SEM path model**

TABLE 9. **Sample characteristics**

Variable	Item	Frequency	Percentage
Gender	Male	100	66.67%
	Female	50	33.33%
Age	20 – 30	80	53.33%
	30 – 40	60	40%
	40 – 50	8	5.3%
	Over 50	2	1.3%
Academic degree	Upper University	1	0.6%
	University	23	15.33%
	College	46	30.67%
	High school	90	60%

To evaluate the reliability and validity of the scale, the two criteria CR and Cronbach's Alpha must be greater than 0.8. The survey results are considered reasonable to start analyzing the PLS-SEM model, see Figure 13, PLS-SEM path Model and the AVE index is greater than 0.5. This proves that the analytical values of the scale are valid and have high reliability to accept the research model. Smart PLS 3.0 software to analyze survey results; The results show that the improvement factor affecting loyalty (H1) has a strong correlation with the P value of 0.01, the factor of convenience. The advantage in using the improved result of the stone surface sander has a strong impact on loyalty (H2) when using the highly improved result with a P-value of 0.00. However, in terms of technical factors, the loyalty interaction is unsatisfactory (H3) with a P-value of 0.54. This shows that from a technical perspective, the

improvement team needs to re-evaluate and consider improving the technical improvement activities for the next improvement activities. The content of the analysis is presented in Table 10.

TABLE 10. Path coefficient, T-value and P-value of PLS estimation

Path	Path Coefficient	T-value	P-value	Result
Useful -> Loyalty	0.33	2.54	0.01	Supported
Convenience -> Loyalty	0.33	2.92	0.00	Supported
Technology -> Loyalty	0.10	0.61	0.54	**Non-supported**

5. Conclusion

Replace the hole grinding wheel with new type, apply the smoothness check system after assembling the product, apply the automatic programing system and the operator safety control system on each stage. The result is productivity up 7.8%, eliminating the step of measuring the surface roughness of the hole after machining, before assembling and smooth defects have not to reduce cost for defects in process. Result to reduce cost in production plan, total cost reduce 33375 USD per year. Details about reduce costs. (1) Reduce cost for reducing defects about 28305 USD per year and (2) Reduce cost for improvement productivity (set/hour) about 5070 USD per years. Rebuild the future value stream map and as a result total lead time is reduced by 20 minutes compared to pre-improvement.

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